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Research article

Urban residents' response to and evaluation of low-carbon travel policies: Evidence from a survey of five eastern cities in China

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ABSTRACT

To address the problems of excessive energy consumption and global climate change, the Chinese government has issued numerous policies to guide urban residents' low-carbon travel behavior. To evaluate the validity of these policies from the perspective of public opinion, this study summarizes 22 policies from the four vantage points of economics, administration, technology, and public information and then measures residents' response to and evaluation of policies based on survey data on 1977 urban residents using stratified random sampling in five cities in eastern China. The results indicate that from the viewpoint of policy response, administrative policies for promoting public transport show the highest degree of response, followed by public information, technological, and economic policies. Specifically, the responses to parking and congestion fee policies are relatively stronger than those to vehicle purchase tax, vehicle and vessel tax, and fuel surcharge policies. Moreover, the responses to fuel surcharge policy are even weaker than car-restriction policies, including license-plate number restriction, license-plate lottery, and license-plate auction policies. From the viewpoint of policy evaluation, administrative policies for promoting public transport obtain the highest evaluations, followed by economic and technological policies. Residents' evaluations of car-restriction and public information policies are the lowest. In addition, a four-paradigm model is introduced to illustrate residents' reactions to each policy in terms of response and evaluation. Finally, several implementation strategies, including the anterior, concurrent, optional, core, supporting, and assisting policy options are proposed to guide urban residents' low-carbon travel behavior.

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1. Introduction

The ongoing trend of urbanization has led to the accommodation of more than half of the world's population in urban areas, and this growing population will in turn have great impact on urban transportation. According to International Energy Agency (IEA) forecasts, the global CO_2 emissions from urban transportation will be increasing at a 1.7% annual growth rate by 2030, and in developing countries at higher rates of 3.4% (IEA, 2010). In recent years, CO_2 emissions from urban transportation have increased significantly in developing countries, especially in China. China's CO_2 emissions in the transportation sector increased by about 9.7 times at an average annual growth rate of 7.4% from 1980 to 2012 (Xu and Lin, 2015). For example, during the period from 2000 to 2011, CO_2 emissions from urban residents' travel have increased by 328% and 205% in Beijing and Shanghai, respectively, with private cars accounting for 84% and 61% of this, respectively (Wang and Liu, 2015).

Many developed countries have come to believe that the car-oriented development mode should be transitioned to the transit-oriented development mode to achieve sustainable urban transportation. A shift from personal transport to public transport (PT), walking, and cycling is vital to avoid sprawl and car-related pollution, and to achieve the Paris agreement's two-degree scenario (IEA, 2016). Hence, travel demand management (TMD), which involves strategies and policies to reduce travel demand or to redistribute this demand from personal cars to walking, bicycling, or PT, is urgently required. Many opportunities exist in cities to curb transport-related carbon emissions by reducing trips and trip distances (e.g., car restrictions and taxes), shifting activity to walking, bicycling, or PT (e.g., investments and subsidies), and progressively

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adopting more efficient vehicles (e.g., technology upgrades) (Lah, 2017). “Reduce” and “shift” options in urban areas would deliver 36%–39% of the required emissions reduction in urban transport, which highlights the strategic relevance of urban planning and TDM policies (IEA, 2016). Based on the experience of developed countries, China's central and local governments have issued a series of taxes, subsidies, investments, and regulations to stimulate the PT development and restrict car uses. However, traffic congestion and pollution problems are still serious, with growing car ownerships and low PT utilizations.

Sustainable transport policy encompasses many related but distinct aspects, such as air quality, health, social justice and welfare. Hence, enough evaluation of the humanity, fairness, and effectiveness of policies from the vantage point of policy implementers should be seriously considered. However, at present, most studies involve econometric analyses that evaluate the impact of a certain policy on a city's economy, well-being, and pollution. The research methods are over-reliant on economic data without sufficient considerations to the public's attitude/acceptance of policy. Because car restrictions may deprive people of their right to “pleasant driving”, people may passively cooperate with these mandatory policies, but express low satisfaction with them, leading to cognitive dissonance and policy resistance. The worst situation is that people find ways to get around a policy or become indifferent to it, resulting in greatly reduced policy effectiveness and sustainability (Schade and Schlag, 2003; Aklin and Urpelainen, 2014; Zhang et al., 2015). For example, car owners may drove “illegally” without obeying the driving restriction rules (Wang et al., 2014), and wealthy people are incline to buy second cars with a different license plate (Eskeland and Feyzioglu, 1997). Therefore, awareness, attitude, acceptance, and response of policy (Khademi and Timmermans, 2014; Liu et al., 2016a; b; Chen et al., 2017) are successively introduced to evaluate the policy effectiveness from the public's subjective perspective. This paper adopted the policy response and policy evaluation, whereas a policy response is defined as the degree of people's behavioral reactions to policy adjustments, i.e., whether or not to perform a specific action due to certain policy adjustments, and a policy evaluation is defined as people's subjective judgment of the importance of various policies.

Under these circumstances, this paper focuses on the low-carbon development, starts from the worldwide issue of urban transportation, and discusses the sustainability of related transport policies. The topic is important in the carbon emission abatement of urban residents' travel and the improvement of social welfare. We discuss what the reasons might be for the widespread advocacy or adoption of policies that may be largely ineffective. These would be very important for policy-maker, not only for carbon emission reduction, but also for atmospheric pollution mitigation of transportation sector in cities. The proposed policy suggestions are helpful for policy-makers to address or adjust the emphasis or priority of transport policy according to their specific development settings and goals.

2. Literature review

Earlier studies about low-carbon travel policies mainly focused on two aspects: promotion of PT systems and restriction to private cars.

In terms of promoting PT systems, most studies state that improving PT infrastructure and management services can promote PT use. For example, local governments need to construct bus rapid transit (BRT) and optimize PT structure, distribution, density, frequency, time, and routes (Van Vugt et al., 1996; Schwanen et al., 2001; Yang et al., 2013; Zhang et al., 2017). Some researchers present that urban transport problems are resulting from unreasonable urban planning, so the governments should attach importance to spatial structural planning, land use and multilevel roads planning, which are proved to significantly affects traffic volume, mobility, and energy consumption. (Nakamura and Hayashi, 2013; Vos and Witlox, 2013; Yang et al., 2013; Bento et al., 2016; Cai et al., 2018). In addition, a decrease of PT fare is demonstrated to have a positive effect in increasing the number of residents willing to use transit for daily travel (Hunecke et al., 2001; Sharaby and Shiftan, 2012; Eliasson and Proost, 2015; Qiang et al., 2017). In the case of restricting private cars, increasing the fuel surcharge has long been advocated by economists as an effective measure to address road congestion and air pollution (Barla and Proost, 2012). Except for fuel surcharges, other taxes and fees such as vehicle purchase taxes, vehicle tonnage taxes, road pricing, road maintenance fees, and parking fees are advantageous in reducing traffic congestion and car-related pollution (Lam and Toan, 2006; Vos and Witlox, 2013; Eliasson and Proost, 2015). Congestion charge, though remains disputed, has been successfully applied by cities and countries, e.g. London, Stockholm, and Singapore, and proved to effectively reduce congestion and air pollution (Button, 2004; Schmöcker et al., 2006; Zheng et al., 2014). In addition, some researchers believe that mandatory car restrictions, e.g. driving restrictions, are conducive to increasing PT use, alleviating traffic congestion, and reducing hazardous pollution. (Lu, 2016; Liu et al., 2016a; b).

Currently, the TDM scheme has been designed and a “soft” management is put forward. In addition to those mandatory regulations, a “soft” TDM scheme aims to provide moderate encouragement to people to adopt cleaner ways of travel by means of technological upgrades and persuasion.

Some researchers believe that low-carbon transport policy must transition from the “reduce” and “shift” strategies to the “improve” options (Lah, 2017), such as from reduction of conventional fuel vehicle (CFV) and shift to non-motorized modes to the improvement of alternative fuel vehicle (AFV) (Dender, 2009; Hickman et al., 2010; Barla and Proost, 2012). With the development of Internet technologies, intelligent transport systems (ITS) and ride-sharing services can reduce the unloaded rate and the exhaust emissions, and induce people's low-carbon travel behavior (Corman et al., 2009; Fagnant and Kockelman, 2014; Chen et al., 2016; Fan et al., 2017). Park-and-ride (P&R), a mode of transferring private vehicles to PT, is helpful in alleviating car-use problems of congestion, parking, and pollution (Lam et al., 2001; Islam et al., 2015; Song et al., 2017). Furthermore, individuals tend to adjust their focus, attitudes, and actions actively to perceived expectations, pressures, and norms derived from surroundings. (Avineri and Waygood, 2013). Therefore, information, advertising, and a low-carbon social atmosphere are conducive to people's low-carbon travel behavior (Anable, 2005; Ahmed et al., 2008; Chen et al., 2014; Geng et al., 2016).

According to existing research, this study summarizes and subdivides these low-carbon travel policies into four categories: economics, administration, technology, and public information (see Table 1). Economic policies refer to measures that aim to affect behavior by adjusting transport-related prices and costs. Administrative policies refer to mandatory orders, instructions, and regulations promulgated by state departments to regulate traffic. Technological policies refer to a new measure or mode based on technical progress in energy, Internet, and other fields. Public information policies, a group of persuasive measures including information, advertising, social opinion, and social culture, aim to strengthen individuals' environmental awareness, norms, motivations, and actions. Accordingly, the study introduced a four-paradigm model, collected empirical data from surveys in

Table 1
The framework of low-carbon travel policies in China.

Categories	Policy items	Policy descriptions
Economic policy	PT fare subsidies	PT fare reductions by government subsidies
	Vehicle purchase taxes	Increase one-off taxes on vehicle' price, including consumption tax and value added tax
	Vehicle and vessel taxes	Increase yearly tax on vehicle tonnage and displacement, similar as vehicle tonnage tax
	Fuel surcharge	Increase fuel taxes (including road maintenance fees)
	Parking fee	Increase the pricing
	Congestion charge (being developed)	Impose fees charged to vehicle users in rush areas and periods of time
Administrative policy	PT density	Cut down the distance from location to PT site
	PT frequency	Shorten the waiting time for PT
	PT route	Shorten the time-consuming of PT
	PT infrastructure	Strengthen bus rapid transit and public bicycle system
	Urban structural planning	PT-oriented land use and urban spatial structural planning
	Road network	Multilevel roads planning
	License-plate number restriction	Car restrictions according to the last digit (single or double digit) of license-plate numbers
	License-plate lottery	Car buyers apply for encodings and then get the vehicle license by lottery
	License-plate auction	Car buyers buy the vehicle license after an open auction with a reserve price
Technological policy	Park-and-ride mode	Commuters travel by private vehicles, gather at a common site and transfer to PT
	Alternative fuel vehicle	Alternative fuel vehicles and supporting facilities
	Ride-sharing service	A model of car rental where people rent cars for short periods of time through the internet.
	Intelligent transport system	Real-time traffic management and terminal applications
Public information policy	Information	Media advertising and travel awareness campaigns
	Social opinion	Norms and expectations from the surroundings, public, and government
	Social culture	Idea, lifestyle, and social atmosphere

PT: Public transport.

representative cities in eastern China, and analyzed urban residents' responses to and evaluations of low-carbon travel policies from a consumer's subjective perspective.

3. Methodology

3.1. Data collection

As shown in Table 2, seven cities in eastern China had already implemented car use or purchase restriction policies at the end of 2016. To achieve representation of different cities in different geographical regions, five cities (Beijing, Shanghai, Guangzhou, Jinan, and Hangzhou) were selected for this study. These selected cities are representative with regard to regional, economic, and policy features, and can effectively illustrate the development direction of low-carbon transport policies in eastern China.

Before the formal investigation, a pre-survey was launched in May 2016 in Xuzhou City in Jiangsu Province. On the basis of relevant literature and expert interviews, we developed a pilot questionnaire and then modified this by giving considerations to the Chinese context. Two hundred sixty questionnaires were provided online, and the effective number recovered was 232. After reliability and validity analysis, appropriate modifications were made based on the pre-survey, resulting in the formal questionnaire. The subjects of the formal investigation were residents of the five selected cities, and the simple random sampling method was used. First of all, two districts were randomly selected in each city, and then two residential areas were randomly selected in each district. Finally, residents were randomly selected in each residential area to receive the questionnaire. Only one representative from each household was allowed to complete the questionnaire. All formal questionnaires have been distributed and recovered through on-site investigation and survey. Considering that the questionnaire contains more items about car-related policies, the sample was readjusted based on car ownership, leading to a higher proportion of respondents owing cars than the national average level. Every respondent completed the questionnaire was able to receive a small gift. Finally, 2500 copies of the formal questionnaire were distributed between July and October 2016, and 1977 valid questionnaires (79%) were recovered. Table 1 in Supplementary Materials (Appendix A) lists the reliability and validity tests of the pre-survey and formal survey. Table 2 in Supplementary Materials (Appendix A) summarizes the sample structure.

3.2. Measures

The questionnaire consisted of three parts. The first part involved basic individual information, including city, gender, age,

Table 2
Selected cities with car restriction policies in eastern China.

Region	City	AAP (thousand people)	APCG (million CNY)	Car restriction policies	Research object	Valid sample
East	Beijing	1253.5	102,338	License-plate lottery, license-plate number restriction	Selected	560
	Shanghai	1367.5	99,095	License-plate auction	Selected	562
	Guangzhou	690.8	128,478	License-plate lottery, License-plate auction	Selected	305
	Shenzhen	321.3	149,495	License-plate lottery, License-plate auction		
	Tianjin	827.2	105,231	License-plate lottery, License-plate auction, license-plate number restriction		
	Hangzhou	520.9	112,322	License-plate lottery, License-plate auction, license-plate number restriction	Selected	285
	Jinan	358.2	95,620	license-plate number restriction	Selected	265

Note: All data are derived from the national research network database in 2014, of which AAP and AAG data are from municipal districts. AAP means annual average population, APCG means annual per capita GDP.

education, marital status, number of family members, type of residence, family monthly disposable income, ownership of private cars, and the main mode of travel.

The second part measured residents' responses to the simulated policies. All items were measured by self-reporting. For example, one question was, “If the government began to increase the fuel surcharge (e.g. 2%–5%) on private cars, would you be likely to consider public transport as your first priority for daily travel?” The Likert five-step scale ranging from 1 (very unlikely) to 5 (very likely) was offered as a range of possible responses, where 5 represented the most favorable response. As shown in Table 3 in Supplementary Materials (Appendix A), the policy response portion of the questionnaire consisted of 22 items, including economic policies (6 items), administrative policies (9 items), technological policies (4 items), and public information policies (3 items). These policies covered two aspects of PT and private cars, whereas 10 items regarding PT were filled in by all respondents (N = 1977), and the remaining 12 items regarding private cars were filled in only by respondents who owned or intended to purchase cars (N = 909 + 581 = 1490). It should be noted that one aim of low-carbon travel policy is to keep a reasonable control on car ownership and utilization, so residents with an intention to buy a car are more likely to have a better understanding of car-related policies, and cannot be overlooked in the demand management. Therefore, this paper tends to regard “intending to buy” category as a car owner.

The third part of the questionnaire, which consisted of three items, measured residents' evaluation of the simulated policies. The first item required respondents to choose the more effective way to promote low-carbon travel between two policy options: promoting PT use or restricting CFV use. The second item was, “Which of the following policy options do you think is more effective in promoting PT use?” The respondents had to choose the kind of policy that they thought was the best among four types of policies: economic, administrative, technological and public information. The third item was, “Which of the following policy options is most effective in restricting CFV use?” Here, the respondents also had to choose one kind of policy among the four policy types. The items included in the questionnaire are listed in the Table 4 in Supplementary Materials (Appendix A).

3.3. Quantitative methods of policy response and evaluation

First, the five response levels for each policy (very unlikely, unlikely, neutral, likely, and very likely) were assigned to (1, 2, 3, 4, 5). Then the values were substituted into Equations (1)–(5) to calculate the response (R) and evaluation (S) of economic (E), administrative (A), technological (T), and public information (P) policies. The calculation formulas were as follows:

$$S_i = R_i{*}W_i, \quad S = \frac{1}{i}\sum_i S_i, \tag{1}$$

$$R_{Ei} = \sum_{j=1}^{5} e_j \frac{n_{ij}}{N_i}, \quad S_E = \frac{1}{6}\sum_{i=1}^{6} R_{Ei}W_{Ei}, \quad e_j = (1,\ 2,\ 3,\ 4,\ 5) \tag{2}$$

$$R_{Ai} = \sum_{j=1}^{5} a_j \frac{n_{ij}}{N_i}, \quad S_A = \frac{1}{9}\sum_{i=1}^{9} R_{Ai}W_{Ai}, \quad a_j = (1,\ 2,\ 3,\ 4,\ 5) \tag{3}$$

$$R_{Ti} = \sum_{j=1}^{5} t_j \frac{n_{ij}}{N_i}, \quad S_T = \frac{1}{4}\sum_{i=1}^{4} R_{Ti}W_{Ti}, \quad t_j = (1,\ 2,\ 3,\ 4,\ 5) \tag{4}$$

$$R_{Pi} = \sum_{j=1}^{5} s_j \frac{n_{ij}}{N_i}, \quad S_P = \frac{1}{3}\sum_{i=1}^{3} R_{Pi}W_{Si}, \quad s_j = (1,\ 2,\ 3,\ 4,\ 5) \tag{5}$$

where S_i is the evaluation value of the i-th policy; W_i is the importance weight of the i-th policy; R_{Ei}, R_{Ai}, R_{Ti}, and R_{Pi} are the response values to the i-th economic/ administrative/ technological/ public information policy respectively; S_E, S_A, S_T, and S_P are the evaluation values of these four types of policies respectively; i is the number of items for a particular type of policy; j is the five response degrees; W_{Ei}, W_{Ai}, W_{Ti}, and W_{Pi} are the importance weights of these four types of policies, respectively; n_{ij} is the sample of the i-th policy with degree of response j; N_i is the total number of samples that differ in the two aspects of PT and cars.

3.4. Four-paradigm model

The four-paradigm model is a management theory used to understand how consumers evaluate a product or service on two dimensions: importance and satisfaction. The four-paradigm model is a qualitative research method introduced by Martilla and James (1977) in connection with marketing research. Since then, the model has been widely used to evaluate public policies, for example by Liu (2014) and Li et al. (2016). Therefore, the four-paradigm model was used here to evaluate low-carbon travel policies on the two dimensions of response and evaluation. Because response to and evaluation of policies are subjective opinions that can be obtained only from consumers, questionnaires were used to obtain the research data. The steps in constructing the four-paradigm model are described below.

The first step is to build an orthogonal plane coordinate system. The vertical and horizontal axes represent the values of policy response and policy evaluation, respectively, for the policies under study. Four quadrants are established by taking the average response value and the average evaluation value as boundaries. The first to fourth quadrants are referred to as High-High (HH), Low-High (LH), Low-Low (LL), and High-Low (HL). Policies in the HH quadrant have policy response and evaluation values that are both higher than average. The LH quadrant contains policies with response values lower than the mean, but evaluation values higher than the mean. The response values of policies in the HL quadrant are higher than average, but the evaluation values are lower. The LL quadrant contains policies with below-average policy response and evaluation values.

4. Results

On a five-point Likert-type scale, higher values mean a stronger intention to choose PT for daily travel, i.e., a stronger response to low-carbon travel policies. Therefore, values above 3 were defined as superior and those below 3 as inferior; these values were used to characterize urban residents' reactions to related policies. The responses for each policy are shown in Table 3 in the body of the text and its frequency distribution in Fig. 1 in Supplementary Materials (Appendix A).

(1) *Responses to economic policies.* In the case of PT fare subsidies, respondents' mean policy responses were high, with 63.4% superior values (SV). However, the proportion of inferior values (IV) was 25.3%, indicating that respondents' policy

Table 3
Mean, SD, SV, IV, and responses to economic, administrative, technological, and public information policies.

		Object	Sample	Mean	SD	SV (Mean > 3)	IV (Mean < 3)	R_i
Economic policies	Congestion charge	Car	1490	3.83	1.33	65.5%	17.2%	3.83
	Parking fee	Car	1490	3.84	1.31	66.1%	19.9%	3.84
	Vehicle and vessel taxes	Car	1490	3.45	1.53	53.3%	27.4%	3.45
	Vehicle purchase taxes	Car	1490	3.29	1.49	47.7%	29.2%	3.29
	Fuel surcharge	Car	1490	3.37	1.45	49.6%	25.8%	3.37
	PT fare subsidies	PT	1977	3.69	1.41	63.4%	25.3%	3.69
Administrative policies	License-plate number restriction	Car	1490	3.73	1.05	60.2%	11.3%	3.73
	License-plate lottery	Car	1490	3.56	1.09	53.2%	14.8%	3.56
	License-plate auction	Car	1490	3.62	1.06	56.3%	12.1%	3.62
	Urban structural planning	PT	1977	4.29	0.86	82.9%	3.7%	4.29
	Road network	PT	1977	4.41	0.76	90.3%	2.4%	4.41
	PT infrastructure	PT	1977	4.36	0.87	85.5%	3.5%	4.36
	PT route	PT	1977	4.14	1.01	75.1%	6.7%	4.14
	PT frequency	PT	1977	4.46	0.86	87%	4.2%	4.46
	PT density	PT	1977	4.05	1.25	70.3%	11.3%	4.05
Technological policies	Park-and-ride mode	Car	1490	3.93	1.11	73.2%	11.5%	3.93
	Ride-sharing service	Car	1490	3.95	1.03	75%	9.8%	3.95
	Alternative fuel vehicle	Car	1490	3.94	1.01	68.4%	7.1%	3.94
	Intelligent transport system	PT	1977	4.34	0.84	88%	3.9%	4.34
Public information policies	Information	PT	1977	4.06	0.96	73.1%	5.1%	4.06
	Social culture	PT	1977	4.09	0.92	76%	4.2%	4.09
	Social opinion	Car	1490	4.16	0.89	81.1%	4.7%	4.16

PT: Public transport.

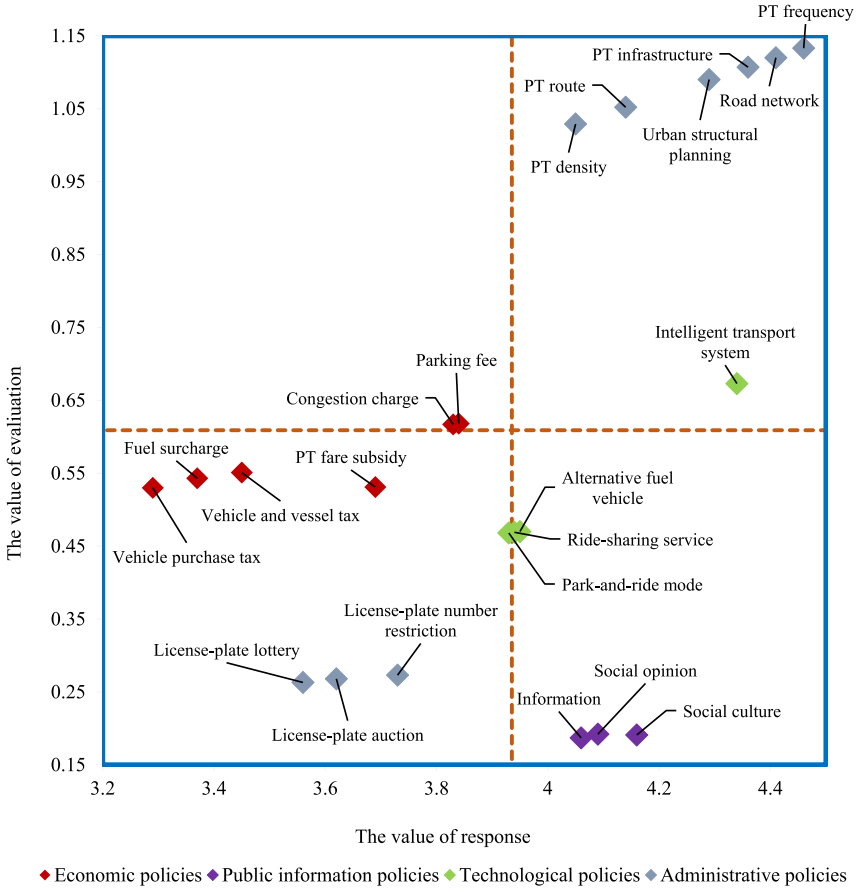

Fig. 1. Results of the four-paradigm model. "PT" means "public transport".

responses to PT fare subsidies showed two distinct distributions. In the case of car-restriction policies, the policy responses to vehicle purchase taxes were the lowest, with 47.7% SV and 29.2% IV. However, the higher mean, lower standard deviation (SD), larger proportion of SV (>65%), and smaller proportion of IV (<20%) express a stronger policy response to increased parking fees and congestion charges. According to the R_{Ei} values calculated by Equation (2), the priorities of respondents' responses to economic policies in descending order were: parking fee ≥ congestion charge >

PT fare subsidy > vehicle and vessel tax > fuel surcharge > vehicle purchase tax.

(2) *Responses to administrative policies.* In the case of improving PT use, responses to road network and PT frequency policies were the strongest, with a smaller SD (<1), a larger mean (>4.4), and a larger proportion of SV (>87%). In the case of the three car-restriction policies, respondents generally expressed fairly negative reactions, with the means and SV proportions of these policy responses being obviously lower than those for PT policy responses. Furthermore, the "likely" and "neutral" response rates for car-restriction policies were greater than 30%, with the IV class accounting for more than 10%. Therefore, most urban residents are more inclined to maintain a neutral attitude or to accept the policies reluctantly. According to the R_{Ai} values calculated by Equation (3), the priorities of respondents' responses to administrative policies in descending order were: PT frequency > road network > PT infrastructure > urban structural planning > PT routes > PT density > license-plate number restriction > license-plate auction > license-plate lottery.

(3) *Responses to technological policies.* According to the response values and their frequency distributions, responses to the technological policies regarding car use were lower than those for PT use. Most respondents did not oppose the development of AFC, but approximately one-quarter of them held neutral or wait-and-see attitudes. In contrast, respondents generally expressed positive attitudes toward ITS. According to the R_{Ti} values calculated by Equation (4), the priorities of respondents' responses to technological policies in descending order were: ITS > ride-sharing service ≥ AFC ≥ park-and-ride mode.

(4) *Responses to public information policies.* As shown in Table 3, whether for PT or car use, respondents expressed a strong and positive response to public information policies, with mean values greater than 4, SD values less than 1, SV greater than 70%, and IV less than 6%. According to the R_{Pi} values calculated by Equation (5), the priorities of respondents' responses to public information policies in descending order were: social culture > social opinion ≥ information.

4.1. Evaluation of the various policies

To evaluate and compare the importance of policies, some items about policy comparisons were included in the questionnaire. The survey results for these items are illustrated in Figs. 2–4 in Supplementary Materials (Appendix A). As shown in these Figures, 59.9% of respondents indicated that PT-promoted policies are more important in promoting low-carbon travel than CFV-restricted policies (40.1% of respondents supported this policy). Specifically, in the case of policies to promote PT, 42.4% of respondents believed that administrative policies were the most important measures, followed by technological (25.9%) and economic policies (24.1%), with the lowest support for public information policies (7.6%). In contrast, in the case of policies to restrict CFV, 40.1% of respondents considered economic policies as the most important measures, followed by technological (29.9%) and administrative policies (18.4%). The support for public information policies was still the lowest (11.6%), but with a slight increase.

Because the four types of policies all include two aspects, it is necessary to calculate all the weights for these policy responses. Here, the different weights (W_i) were calculated and shown in Table 5 in Supplementary Materials (Appendix A). The weight of administrative policies for promoting PT was the highest (0.254), followed by economic policies for restricting CFV (0.161). The weight of administrative policies for restricting CFV, by contrast, was much lower (0.074). In addition, the weight of technological policies, whether for improving PT (0.155) or for restricting CFV (0.119), are relatively higher. In contrast, the weights of public information policies are the lowest (0.046 and 0.047), indicating that people's demand for theoretical and emotional persuasion on topics such as empathy, morals, media, and culture is hardly urgent.

Finally, in combination with the related values (R_{Ei}, R_{Ai}, R_{Ti}, and R_{Pi}) and their weights (W_i), the evaluation values for specific policies (S_i) and the four policy aspects (S_{Ei}, S_{Ai}, S_{Ti}, and S_{Pi}) can be calculated by Equations (1)–(5). As shown in Table 4, administrative policies for improving PT received the highest policy evaluations ($S_i > 1$), followed by economic and technological policies ($S_i \in (0.45–0.7)$). The evaluations for CFV-restriction policies were lower ($S_i < 0.3$), as were those for public information policies ($S_i < 0.2$).

4.2. Four-paradigm model based on policy responses and evaluations

In accordance with the results presented above, a four-paradigm model for further analyzing policy responses (R_i) and evaluations (S_i) was developed and is illustrated in Fig. 1. The results were as follows:

(1) HH quadrant. Seven of the 22 policies belong to this quadrant, including the six PT-related administrative policies and the one PT-related technological policy (ITS). Respondents

Table 4
Evaluation of different types of policies.

Four types	Policies	R_i	S_i	S	Four types	Policies	R_i	S_i	S
Economic policy	Congestion charge	3.83	0.62	0.57	Administrative policy	License-plate number restriction	3.73	0.27	0.27
	Parking fee	3.84	0.62			License-plate lottery	3.56	0.26	
	Vehicle and vessel taxes	3.45	0.55			License-plate auction	3.62	0.27	
	Vehicle purchase taxes	3.29	0.53			Urban structural planning	4.29	1.09	1.09
	Fuel surcharge	3.37	0.54			Road network	4.41	1.12	
	PT fare subsidies	3.69	0.53			PT infrastructure	4.36	1.11	
Public information policy	Information	4.06	0.19	0.19		PT route	4.14	1.05	
	Social opinion	4.16	0.19			PT frequency	4.46	1.13	
	Social culture	4.09	0.19			PT density	4.05	1.03	
Technological policy	Park-and-ride mode	3.93	0.47	0.52					
	Ride-sharing service	3.95	0.47						
	Alternative fuel vehicle	3.94	0.47						
	Intelligent transport system	4.34	0.67						

PT: Public transport.

were inclined to have high responses to and high evaluations of these policies.

(2) LH quadrant. Two economic policies (congestion charge and parking fee) are located in this quadrant. Their values were slightly higher than average evaluation value and slightly below average response value, which were higher than those of the other economic policies, which are located in the LL quadrant.

(3) HL quadrant. Three car-related technological policies and all public information policies belong to this quadrant. Respondents were more willing to exhibit low-carbon travel behaviors under policy guidance of this kind, but did not seem to consider these policies as more important than PT-related administrative policies.

(4) LL quadrant. The rest of the policies are located in this quadrant, including four types of economic policy (PT fare subsidy, vehicle purchase tax, vehicle and vessel tax, and fuel surcharge) and three types of car-related administrative policies. Interestingly, in the case of restricting CFV, respondents tend to express higher evaluations (but lower responses) for economic policies than for administrative policies. In addition, people's reactions to PT fare reductions were relatively weaker than to imposing congestion charge and increasing parking fee.

5. Discussion

Economic stimulus and administrative restrictions are the most controversial issues in promoting sustainable urban transportation. Increases in fuel surcharge and tax are advocated as an effective measure for handling the external costs associated with energy consumption (Barla and Proost, 2012). However, the results of this study have indicated that increased fuel surcharges and purchase taxes had a relatively low response, even lower than mandatory car-restriction policies. Enoch and Nakamura (2008) suggested that, compared to fuel charges and taxes, purchase and vehicle taxes have a stronger effect on car purchases, but a weaker effect on car use. People may generally accept vehicle charges and taxes, but the high cost of buying a car seems to push people to use it as much as possible as a way of getting value for money. Instead, fuel surcharge and tax are more conducive to reductions in car use and greenhouse gas emissions (Enoch and Nakamura, 2008; Gallo, 2011). It seems that very few taxes may give messages to motorists to use their cars more sensibly, but the same policy in different countries may bring about different effects (Busse and Zettelmeyer, 2013). However, because oil consumption reductions will be watered down by price responses, causing increased consumption in other places and in the future, the cost-effectiveness of current carbon-restricting transport policies based on oil consumption remains debatable (Eliasson and Proost, 2015). Just as shown in this study, responses to and evaluations of increases in fuel surcharge are lower than the parking fees and congestion charges. Therefore, it seems that these not oil-related policies, such as the parking fees and congestion charges, will probably restrain carbon emissions in the transport sector and be more effective as car-restriction measures in a long time (Button, 2004; Schmöcker et al., 2006; Enoch and Nakamura, 2008; Zheng et al., 2014). In addition, the PT financial subsidy policy has long been considered as a high-impact way to promote low-carbon travel behavior (Eliasson and Proost, 2015). Somewhat surprisingly, the responses to PT fare subsidy, as described in this study, were weaker than to parking fee and congestion charge. The reason for this may be that people are more sensitive to large-scale information such as parking fee and congestion charge than to small-scale information such as a slight fare reduction (Levin et al., 1998).

Lu (2016) and Liu et al., 2016a,b suggest that car-restriction policies have notable consequences for increasing PT use, alleviating traffic congestion, and reducing hazardous pollution. However, some researchers hold the view that such restrictions have no significant influence on individuals' decisions to drive (Wang et al., 2014) and cannot effectively reduce vehicle pollution (Chen et al., 2011; Viard and Fu, 2015). Eskeland and Feyzioglu (1997) stressed that car-restriction policies cause a greater decline in social well-being than in the optimal state and are less effective than economic policies such as fuel tax and congestion charge. Nevertheless, the results of this study indicate that people may have a low opinion (evaluation) of, but still somewhat/reluctantly obey (response to) the car-restriction policies, and this strength of policy response is greater than to the economic penalties and taxes.

Technological upgrades and persuasion are considerable management strategies. According to people's substantially positive reactions to technological policies, traditional widely used economic and administrative policies do not fully cover the public's need for technological developments in urban transportation. Ride-hailing, car-sharing, park-and-ride mode, AFV, and ITS services are satisfying individuals' diverse demands for mobility and may be a clever strategy than those mobility reduction and PT-use persuasion measures for car-dependent residents (Dender, 2009; Hickman et al., 2010; Barla and Proost, 2012; Geng et al., 2017). In addition, public acceptance is crucial for the implementation of technologies (Costa et al., 2017). The popularity of technology must be supported by promoting changes in people's ideas. However, the results of this study show that residents currently do not believe persuasion as an insistent demand. One reason for this may be that current information measures involve an overload of messages about the negative consequence of car use. This blind blame may induce car users to believe mistakenly that the government is exaggerating the problem and depriving them of their right to “pleasant driving” (Geng et al., 2016).

6. Policy suggestions

Here on the basis of the values of policy responses and evaluations, several strategies are proposed in Table 5 according to four aspects: policy effectiveness, policy importance, demand urgency, and policy priority. They are helpful for policy-makers to address or adjust the emphasis or priority of low-carbon transport policy according to their specific development settings and goals.

As described in Table 5, according to the indicators of policy effectiveness (response) and policy importance (evaluation), demand urgency of different types of policy is concluded, and finally policy priority (implementation strategy) is proposed. Overall, relevant policies must ultimately be optimized by improving PT-related facilities, services, and maintenances (anterior and core strategy), developing effective economic incentives and control (concurrent and core strategy), supporting technological upgrades (anterior and supporting strategy) and mandatory driving-restriction measures (optional strategy), and assisting public information policies (concurrent and assisting strategy) to guide people's low-carbon travel behavior and finally to achieve the goal of sustainable development of urban transportation.

Specifically, in the case of economic policies, compared to car purchase taxes and fuel taxes, more elastic measures for car-users' demand management such as parking and congestion charges should be emphasized and strengthened. This approach would encourage residents to understand that the economic constraints are aimed to solve their life-related problems such as road congestion and car pollution, rather than to increase government revenue at the expense of their well-being. In addition, people

Table 5
Features and implementation strategies of low-carbon travel policies.

	Economic policies	PT-related administrative policies	Car-related administrative policies	Technological policies	Public information policies
Policy responses (mean values)	3.58	4.29	3.64	4.04	4.10
Policy evaluation (mean values)	0.57	1.09	0.27	0.52	0.19
Policy effectiveness	Relatively effective	Very effective	Relatively effective	Effective	Effective
Policy importance	Important	Very important	Relatively important	Important	Relatively important
Demand urgency	Relatively urgent	Very urgent	Less urgent	Urgent	Relatively urgent
Policy options	Concurrent and core	Anterior and core	Optional	Anterior and supporting	Concurrent and assisting

cannot deeply and directly perceive the economic benefits brought about by their modal split shifts from cars to PT. For this reason, a personal carbon trading scheme can be designed for urban traffic system in the future (Li et al., 2018). For example, the government sets up a carbon account and allocates emissions credits to individuals according to a total budget of urban traffic carbon emissions. Individuals need to surrender certain credits when using different modes of transport (based on carbon credits payment mechanism) and purchase additional credits from others if they want to keep using high emissions vehicles (based on carbon credits trading mechanism). The government can make a reward, subsidy, or punishment according to the emissions credits from individuals, PT operators and gas stations. This scheme is expected to provide market-based incentives so that individuals can reduce the emissions associated with their travel activities, such as by using PT instead of cars.

In the case of administrative policies, driving restriction policies, although they elicit many questions and complaints, will remain as an indispensable tool in increasing PT use, alleviating traffic congestion, and reducing hazardous pollution for policy-makers in developing countries (Lu, 2016; Liu et al., 2016a; b). However, such measures must be implemented in conjunction with support policies involving PT-related facilities, services, land use, and urban planning, and will be used in emergency circumstances with caution.

In the case of technological policies, the traffic technology revolution is increasingly attracting the public's attention. Hence, technological measures have become the development trend in sustainable urban transportation. However, a question worthy of careful consideration is how to provide positive technology experience and maintenance service so as to avoid emotional and economic losses from the CFV switching to other modes (Morris and Guerra, 2015; Geng et al., 2017). In addition, technological policies must be supported by economics, regulations, and laws, and most importantly by changes in people's concept of travel. This low-carbon concept is one of the key issues in solving traffic problems and cannot be formed without the assistance of a public information policy.

Public information and education are always considered as essential and effective ways to form people's ecological awareness and attitudes by means of internal self-motivation (Geng et al., 2017). However, a better-targeted and group-specific travel behavior strategy is likely to be more effective than a “one-size-fits-all” approach. Considering people's greater willingness to accept PT-related messages (Bamberg, 2006), more tailored information and advertising for PT uses will be a more effective strategy (Geng et al., 2016). In addition, the government can set up typical communities, families and individuals with the honorary titles of “low-carbon model”, and arrange community activities/competitions that have wide influence on the public to engage in low-carbon travel behavior.

7. Conclusions

First of all, by analyzing policy responses, it is clear that urban residents are more willing to use PT instead of car for their everyday trips when policies are oriented towards promoting PT rather than restricting car purchase and use. Specifically, responses to PT-related administrative policies were the strongest, followed by public information, technological, and economic policies. Furthermore, responses to vehicle purchase taxes, vehicle and vessel taxes, and fuel surcharge taxes were even weaker than those to administrative car-restriction policies. In contrast, people are more inclined to accept economic policies like parking and congestion fees.

Second, by analyzing policy evaluation, policies that promote PT were found to be more important than policies that restrict CFV. Specifically, for PT improvement, administrative policies were regarded as the best approach, whereas for CFV restriction, economic policies were judged to be the best. Public information policies were regarded as the least important measure. Overall, the priorities of respondents' policy evaluations in descending order were: administrative policies for promoting PT > economic policies ≥ technological policies > administrative policies for restricting CFV > public information policies.

Third, by analyzing the four-paradigm model, it was found that PT-related administrative policies and the ITS technical policy had high responses and high evaluations among respondents, whereas parking and congestion fees had low responses and high evaluations. Public information and other technological policies had high responses, but low evaluations. Car-restriction administrative policies and economic policies had low responses and low evaluations. In addition, several implementation strategies, including the anterior, concurrent, optional, core, supporting, and assisting policy options are proposed which are helpful for policy-makers to address or adjust the emphasis or priority of low-carbon transport policies.

Finally, we acknowledge the limitations of the statistical results from the survey research. An objective evaluation of merits and effectiveness of transport policies is not furnished. In addition, broader samples can provide a more comprehensive understanding of urban residents' acceptances and evaluations of transport policies.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.jenvman.2018.03.091.

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